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Table IX contains the principal orbital elements, so far as known, for sixteen stars of this class, arranged in the order of their periods. A most peculiar discovery concerning these systems, as described in the last two columns of the table, was made by ALBRECHT several years ago: each star has its maximum brightness at or near the time of most rapid approach *toward the observer,* and its minimum at or near the time when receding most rapidly *from the observer.* Orbits of enough stars in this class have been investigated to guarantee, beyond reasonable doubt, the conclusion that the time of maximum in each of the systems is a function of the observer's position in space. Many theories to account for this strange phenomenon have been advanced and discussed, only to be found wholly or largely unsatisfactory.

Several additional conclusions can be drawn from the data. The ratios in the second column from the last indicate clearly that the masses of the companion stars are very small in proportion to the masses of their primaries. The column "a sin i" declares that the primaries revolve in orbits whose dimensions may be described as minute.

It is reasonably certain that all *Cepheid-Geminid* variables, as well as *Algol* variables, are spectroscopic binary systems. The future will probably establish the fact that the cluster variables are binaries.

The importance of spectroscopic binary investigations, in their bearing upon questions of the origin and development of multiple star systems, can scarcely be overestimated.

NOTES ON SOLAR MAGNETIC FIELDS AND RELATED PHENOMENA.

By GEORGE E. HALE.

CLASSIFICATION OF SUN-SPOT LINES.

A study of the Zeeman effect in the spectra of sun-spots has made it necessary to formulate a system of classification of the numerous types of lines observed under various conditions. Before the present work was undertaken, spot spectra were known to include band lines, belonging to the flutings of such compounds as titanium oxide, magnesium hydride, and calcium hydride (or possibly magnesium and calcium in the presence of hydrogen); strengthened lines, many of which are widened; weakened lines; lines which are completely obliterated; reversed lines; thinned lines, and winged lines. The presence of broad wings like those of the D lines may or may not be caused by the magnetic field, but the evidence thus far obtained is opposed to this explanation. The effects which have been clearly proved to be due to the field include the widening of many lines, some of which are of uniform intensity, while others are strengthened or weakened at the center; the separation of a few lines into quadruplets and of many others into doublets, which have been shown by laboratory experiments to be quadruplets, the outer members of each pair being too close for resolution in the comparatively weak field of the sun-spot; and the formation of triplets. In the triplets a great variety of phenomena are observed. In some cases the central line is very weak, while in others it is twice as strong as the side components. Again, all three components of a triplet may appear sharp, while under other conditions the central line of the same triplet may be sharp and the side components broad and diffuse. In the same spot spectrum triplets showing a uniform separation across the umbra may be accompanied by others in which the side components converge. Again, a line may be triple on one side of a spot and double on the other, as the result of a gradual change in the intensity of the central component.

When a Nicol is used the variety of phenomena is considerably increased. For example, it is possible, under certain conditions, using a Nicol without rhomb or quarter-wave plate, to cut off one of the side members of a triplet, leaving the other side member of normal intensity. Such an effect results from the elliptic polarization produced by the mirrors of the tower telescope. Without such polarization the side components would be affected alike by the Nicol, unless used with a rhomb or quarter-wave plate, when either could be extinguished at will. Another interesting phenomenon has also been observed with the Nicol. If it is set in a certain position, the central line of a triplet may be strong on one side of the umbra and weak on the other. Rotation of the Nicol through 90° reverses the relative intensities.

On account of the comparative weakness of the field in spots, many triplets and quadruplets are not completely resolved, but merely widened. By the use of a Nicol the central components of such lines can be reduced in intensity or cut out completely. Final decision whether a given line is a triplet or a quadruplet must be based upon comparison with laboratory results, since the inner components of some quadruplets are so close together as to cause these lines to appear like triplets, unless the magnetic field is very strong.

A tentative system for briefly designating all of these different types of lines has been adopted, for use in tables of wave-lengths and other places where lengthy descriptions cannot be employed.

DIRECTION OF THE AXIS OF THE ELECTRIC VORTEX.

In a normal triplet, observed at right angles to the lines of force in the laboratory, the central line is twice as intense as the side components. When observed parallel to the lines of force, the central line disappears completely. Thus the ratio of the intensities gives a means of determining the angle between the lines of force and the line of sight. Such a triplet as λ 6302.71 (iron) appears under widely different aspects in the spectra of sun-spots. In some cases the central line is weaker than the side components, while in others it is twice as intense. Such differences of intensity, however, are not due solely to differences in the inclination of the axis of the electric vortex to the line of sight. To determine the true relative intensities of the lines we must take into account the polarization resulting from reflection on the silvered mirrors of the tower telescope, the polarizing effect of the grating of the spectrograph, and the rotation of the plane of polarization produced by the spot vapors, which is discussed below. In order to interpret the photographs we must therefore measure the polarization phenomena due to the tower telescope, and for this purpose a special instrument has been constructed. In this instrument a monochromatic light source can be set at the declination and hour angle of the sun recorded at the time of observation. The light from the source is plane or circularly polarized with the aid of a Nicol, used with or without a quarter-wave plate. The parallel beam then falls on the mirror of a very small cœlostat, from which it is reflected to a second mirror, both being set in precisely the same relative positions that the mirrors of the tower telescope occupied at the time of observation. The polarization phenomena thus produced are measured with the aid of a Nicol, used alone or in conjunction with a quarter-wave plate. In this way the change of intensity of any type of line caused by the tower telescope can be determined.[1]

As ZEEMAN has shown, rotation of the spectrograph is in itself sufficient to reverse the relative intensities of the central and side lines of a triplet. Hence the position angle of the spectrograph at the time of observation must be known, in order to determine the true relative intensities of the lines. But even this is not sufficient, because of the change in intensity of different parts of the central line of a triplet sometimes observed when the Nicol is rotated. However, by finding the two positions of the Nicol giving the *maximum* intensity of the central and the side lines of a triplet at the center of the umbra, the inclination of the lines of force to the line of sight can be determined.

ROTATION OF THE PLANE OF POLARIZATION OF LIGHT EMITTED IN SUN-SPOTS.

FARADAY discovered in 1846 that when plane polarized light is passed in the direction of the lines of force through a block of heavy glass in a magnetic field, its plane of polarization is rotated. It was found later that other substances in the magnetic field, including metallic vapors, produce the same effect. In a sun-spot the central line of a triplet is a source of plane polarized light. If this passes toward the observer along the lines of force of the magnetic field, its plane of polarization must be rotated. Hence the degree of absorption at higher levels in the spot vapors, which determines the total intensity of the line, must be affected. In this way we may probably account for the phenomena observed in certain triplets. As already remarked, when the Nicol is placed in a certain position, the central line of a triplet is found in some spots to be strong on one side of the umbra and weak on the other. When the Nicol is turned through an angle of 90°, the line becomes strong on the side of the umbra where it was previously weak and weak on the side where it was previously strong. If the effect is due to the rotation of the plane of polarization, we should expect a similar phenomenon to appear in the case of the side members of the triplet. In general, the light does not come exactly along the lines of force, but makes a considerable angle with them. Under these circumstances the side members of triplets are elliptically polarized. The circularly polarized component of this light is not visibly affected by transmission through the vapor. The plane of polarization of the plane polarized component must, however, be rotated. As the plane of polarization of the side members is at right angles to that of the central line, the effect ought to be opposite in sign to that given by it. Moreover, it should be less in degree, since the circularly polarized component of the light will remain of unchanged intensity. Just such an effect is actually observed in sun-spots. There can therefore be little doubt that we are observing the phenomenon of the rotation of the plane of polarization in the spot vapors.

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[1] In certain cases the polarization phenomena produced by the mirrors actually employed with the tower telescope are measured directly.

On this hypothesis the difference in intensity of the central line on opposite sides of the spot must be due to a difference in the thickness or density of the vapor, or the strength of the field, in the two positions. However, another effect may enter here to complicate the question. It has already been mentioned that in some cases triplets are observed, without a Nicol, in which the central line is strong on one side of a spot and weak on the other. The polarizing effect of the grating of the spectrograph may be sufficient to give rise to such a phenomenon, even without a Nicol, in accordance with the hypothesis outlined above. Another cause might be a difference in the direction of the field on opposite sides of the spot. As we have other reasons for believing that such a difference in the direction of the field must sometimes exist, it is evident that a careful series of observations must be carried out in order to separate the two classes of phenomena. As already remarked, however, such complicating effects need not prevent us from determining the angle between the lines of force and the line of sight, provided that the polarizing effects of the tower telescope and spectrograph be allowed for, and the maximum intensities of the central and side lines of the triplet be determined by turning the Nicol to the proper positions.

STRENGTH OF THE FIELD IN DIFFERENT PARTS OF A SPOT.

In general, the separation of the components of a triplet is greatest near the center of the umbra, and decreases gradually until the outer boundary of the penumbra is reached, where the line is of about its normal width. However, certain spot lines are widened beyond the limits of the penumbra and even at points some distance away. To determine the presence of very weak fields, the following device serves to good advantage. Using a Nicol and rhomb, set so as to transmit one of the outer components of a triplet, a photograph of the spectrum is made. During the exposure a small metal plate, containing a series of holes 1^{mm} in diameter and 1^{mm} apart, is mounted just above the slit of the spectrograph. After the exposure the plate is moved through a short distance, so as to bring another set of holes into position above the slit, in order to uncover those regions which were covered during the first exposure. The Nicol is then turned through 90°, so as to transmit the opposite component of the triplet, and a second exposure is made. As the alternate strips of spectra on the plate then show the opposite components of the triplet, even a very weak field produces a sufficient displacement of the line to show itself. A better arrangement, which I am about to employ, will be afforded by the use with the Nicol of narrow strips of mica (quarter-wave plates), mounted so that the principal planes of adjoining strips are at right angles to one another. A single exposure will then give all of the spectra simultaneously.

In some spots the maximum strength of the field is not found at the center of the umbra. Furthermore, as already mentioned, we sometimes find in the same spectrum triplets or quadruplets the components of which are parallel in some cases and convergent in others. We must be dealing in the latter instance with phenomena produced at different levels.

STRENGTH OF THE FIELD AT DIFFERENT LEVELS.

In my paper "On the Probable Existence of a Magnetic Field in Sun-Spots,"[1] I showed that while four lines of iron indicated nearly equal field-strengths in a spot, lines of titanium and chromium gave widely different values. These were attributed to differences in the mean level represented by the absorption of these lines. This hypothesis has received support from various directions. It is found, for example, that while substances like iron and other elements which lie at a comparatively low level in the solar atmosphere indicate a field strength as great as 4,500 units, the high-level *b* lines of magnesium and the D lines of sodium give a very weak field, while no field can be detected with the hydrogen lines. Furthermore, as mentioned above, parallel and convergent lines occur on the same plate. There is no great difficulty in assuming that the rate of change in the strength of the field from one side of the umbra to the other may be different at different levels, whereas we could not easily explain such an effect if vapors lying at the same level were supposed to produce it.

STRENGTH OF THE FIELD AT DIFFERENT PERIODS IN THE LIFE OF A SPOT.

The earlier observations indicated that large spots gave stronger fields than small ones, and this suggested that differences in the strength of the field might be expected at different periods in the life of a spot. Such changes have been found. In connection with this investigation the life history of each spot is carefully studied, especial attention being directed to such phenomena as the area of the spot, the type of the spot, the area of the calcium flocculi, the visibility and curvature of the stream lines in the $H\alpha$ vortices, the number and activity of eruptive phenomena, etc.

METHOD OF MAPPING THE MAGNETIC FIELDS OF THE SUN.

One method of detecting the existence of weak magnetic fields outside of spots has already been described. Another, which serves especially for the study of the stronger fields in different parts of the umbra and penumbra, and in the several spots of a group, may now be mentioned. A large solar image is necessary. The spectrograph is provided with a multiple slit, so constructed as to permit the spectra given by a series of parallel slits about 2^{mm} apart to be photographed simultaneously on the same plate. It is not considered sufficient to record only a single line: several lines are needed in order to give the field-strength at different levels. One of the best regions that can be chosen is that lying on both sides of the quadruplet λ 6301.72 and the triplet λ 6302.71, as this contains many interesting lines. A rhomb or quarter-wave plate is used with the Nicol, which is set so as to transmit one of the outer components of a triplet. Suppose the slits to be set across a spot group, and consider the appearance of the lines in an actual case (September 25, 1909) where one of the slits crossed the umbra and penumbra of a large spot and passed through a small spot lying just within the edge of the same penumbra. One side member of such a triplet as λ 6302.71 was completely cut off. The other appeared as a curved line, departing toward the violet from its normal position near the edge of the penumbra, reaching a maximum displacement in the umbra of the spot, and then curving gradually back as it approached the other edge of the penumbra. Just before reaching the small spot it returned sharply to its normal position, then continued across to the opposite (red) side of the line, returning to the normal position at the point where the slit passed beyond the small spot. We have here a case where the polarities of the large umbra and its enveloping penumbra were of one sign, while that of the small spot lying within the same penumbra was of the opposite sign. Three other small spots within the same penumbra were also opposite in polarity to the large spot. In other cases all of the spots in the same group have been found to be of the same polarity. It is evident that the photographs permit the strength of the field, as well as the polarity, to be determined at many points within a spot group. In some cases it may be advantageous to use a multiple mica quarter-wave plate, made up of narrow strips, as described above. To complete the record, a device may be used for photographing a series of parallel images of any desired line on a plate, at the same distance apart as the slits of the spectrograph. Superposed upon such a photograph, an *Hα* image of the spot, reproduced from a spectroheliograph plate, will serve to show the direction of curvature of the stream lines of the vortices in all parts of the field.

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[1] *Contributions from the Mount Wilson Solar Observatory*, No. 30; *Astrophysical Journal*, **28**, 329, 1908.

PAIRS OF SPOTS OF OPPOSITE POLARITY.

In a previous paper[1] I have briefly alluded to a pair of spots, of opposite polarity, which appeared to be physically related. The principal reasons favoring this connection were the structure of the vortices on the $H\alpha$ photographs, the fact that the axes of the vortices were considerably inclined to solar radii passing through the spots, and the eruptions found by Fox and Abetti to extend completely across from one spot to another.[2] Furthermore, the rapid decrease upward in the strength of the field in spots pointed to the view that the electric vortex which produces the field must lie at a low level, presumably within the photosphere. As Emden's solar theory assumes the existence of such vortices, it was remarked that the evidence then available seemed to favor this theory.

Since that time various other cases of apparently related spots, of opposite polarity, have been observed. Some of these are very remarkable, the appearance of the $H\alpha$ photographs being such as to resemble closely the lines of force of a bar magnet, the opposite ends of which are supposed to coincide in position with the two spots. The relationship between the curvature of the $H\alpha$ flocculi and the observed polarities is so close that the relative polarities of two neighboring spots may almost always be correctly inferred by an examination of the flocculi on any $H\alpha$ plate.

NATURE OF THE HYDROGEN FLOCCULI.

On June 17, 1909, I discussed before the Royal Society various hypotheses which have been advanced to account for the hydrogen flocculi. When preparing my paper for publication, I confined myself to a brief consideration of the hypotheses advanced by Lockyer, Deslandres, Julius, and myself, arriving at the conclusion that the dark hydrogen flocculi are, in the main, absorption phenomena.[3] The problem of explaining the changes in the structure of the flocculi, as shown on photographs exhibited at the meeting, was reserved for subsequent discussion, when the reduction of the photographs could be completed. Although this work is still in progress, it seems desirable at the present time to refer to its bearing on BRESTER's aurora hypothesis of the hydrogen flocculi.[1] In his paper it was first suggested that the phenomena shown on *Hα* plates are not hydrodynamical, but correspond with the auroras of the earth's atmosphere, as explained by BIRKELAND and others. In BRESTER's opinion, electrically charged particles, supposed to be emitted by radio-active substances in sun-spots, pass out through the solar atmosphere, where they produce luminescence. According to BIRKELAND's theory, the form of the aurora is determined by the earth's magnetic field. The same hypothesis, applied to the Sun, requires that the configuration of the flocculi be governed by the magnetic field in spots. DESLANDRES has recently advocated a similar view.[2]

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[1] "Sur les Champs Magnétiques des Taches Solaires," *Journal de Physique*, July, 1909.

[2] *Astrophysical Journal*, **29**, 40, 1909.

[3] "On the Nature of the Hydrogen Flocculi and Their Structure at Different Levels in the Solar Atmosphere."—*Proceedings of the Royal Society*, A. **83**, 177, 1909.

Let us consider the conditions which may affect the intensity of the flocculi. Bright eruptive flocculi, which are usually of short life and change rapidly in form, are shown in spectroheliograms made with H_2 and the center of *Hα*, but ordinarily they do not appear when the camera slit is set on H_1 or on the edge of *Hα*. If these were eruptions of intensely heated vapor, we should expect their brightness at the photospheric level to be at least as great as at higher altitudes, where the effect of expansion would naturally tend to cool the vapor. It thus seems probable that the exceptional brightness of these eruptive regions is due to some effect experienced by the vapor after it has passed above the H_1 level. A separation of the positive and negative ions in the moving mass of gas might result in electric discharges similar to lightning. If the discharges could be assumed to persist for a sufficient time, the brightness of the eruptive vapor might perhaps be accounted for in this way. Or electrons, emitted in great numbers under the low pressure of the region into which the vapor has suddenly been transported, might contribute materially to the luminescence of the mass. As terrestrial magnetic storms are usually found to be associated with sun-spot groups in which eruptions are numerous, it seems probable that such eruptions may contribute largely to the stream of electrons which pass from the Sun's atmosphere to that of the Earth. It should be noted that these bright eruptive regions exhibit little (if any) of the curved structure which causes the dark $H\alpha$ flocculi to resemble vortices.

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[1] Amsterdam Academy of Sciences, January 30, 1909.

[2] *Comptes Rendus,* January 10, 1910.

These dark flocculi, as explained in the paper mentioned above, are probably due in the main to the absorption of comparatively cool hydrogen. Nevertheless, their changes are sometimes such as to suggest the possibility that the absorption may be partially offset by the luminescence arising from streams of electrons.[1] On June 3, 1908, a large dark hydrogen flocculus was photographed by Dr. ST. JOHN just as it was being sucked into a spot. I cannot account for this phenomenon except as representing an actual flow of absorbing hydrogen toward the spot. The fact that the outline of the flocculus was still faintly visible on the last photograph of the series does not seem to me to oppose this view, since only the gas at a comparatively high level may have been swept into the vortex. In most other cases, however, the curved hydrogen flocculi near spots, which resemble the lines of force in a magnetic field, do not show such evidences of actual motion. On the contrary, their intensity changes are sometimes periodic in character, the dark flocculi appearing strong in some photographs, weak in later ones, and strong again in still later images. I have studied such phenomena on long series of photographs made at intervals of about one minute, and have been forced to the conclusion that the hydrogen of the dark flocculi must undergo more or less periodic changes, such as might result from an intermittent bombardment of electrons.

In considering this question, we must not overlook other possible causes of such changes, such as differences in the volume, pressure, temperature and level of the gas. Certain phenomena are most easily explained as eruptive prominences, seen in projection against the Sun. A notable case of this kind is illustrated by a series of photographs made with $H\alpha$

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[1] Electric discharges or other causes of luminescence may increase the brightness of certain regions, but I fail to see how the formation of flocculi much darker than the general background can be accounted for in this way.

on September 10, 1908. At 6^h 33^m a small, brilliant flocculus could be seen on the edge of a sun-spot. Its brightness and area increased rapidly, reaching a maximum about 6^h 39^m. Meanwhile, a dark flocculus appeared on the outer edge (away from the spot) of the bright area. At 6^h 43^m the area of the bright flocculus was less than half as great as at 6^h 39^m, but the dark flocculus extended away from the spot as a long streamer, apparently of cooler gas falling back toward the Sun. Eight minutes later it attained its greatest length, and was very dark at its outer end. At 7^h 0^m no trace of the bright flocculus remained, and the dark flocculus was shorter and less intense.

SPECTROHELIOGRAMS SHOWING ASCENDING AND DESCENDING FLOCCULI.

Photographs made by Mr. ELLERMAN and myself with the 30-foot Littrow spectroheliograph of the 60-foot tower telescope seem to afford a useful means of distinguishing between ascending and descending gases in eruptive phenomena. The mirror ordinarily used behind the 60° prism of the spectroheliograph is replaced by two mirrors, so adjusted as to give two parallel spectra in the focal plane of the camera objective. Thus two images of the $H\alpha$ line are obtained with light from a single collimator slit. By the use of two camera slits, one set on the red edge of $H\alpha$ in one spectrum, the other on the violet edge of the same line in the other spectrum, two photographs of the flocculi can be taken simultaneously.

In some eruptions, the bright reversal of $H\alpha$ seems to be confined to the central part of the line, so that such phenomena are not shown when the camera slit is set near the edge. In other cases, however, $H\alpha$ is brightened across its entire width. A remarkable eruption photographed on May 12, 1909, was of the latter class. The image obtained with the violet edge of the line shows extensive bright flocculi, lying between two spots. These also appear, with some differences in form, in the image given by the red edge. The latter shows, in addition, a remarkable group of dark flocculi, which appear as a series of nearly parallel straight lines in the space between the spots, and as curved lines, resembling lines of force, at greater distances from the line joining the spots. If the dark flocculi shown only by light from the red edge of the line actually represent descending masses of cooler gas, the method is likely to prove of service in further studies of such phenomena. The dispersion used was that of a single 60° prism of ethyl cinnamate, twice traversed by the light, employed with a combined collimating and camera objective of 30 feet focal length. With higher dispersion it should be possible to photograph separately ascending and descending gases which do not differ greatly in radial velocity.[1]

NATURE OF THE VORTEX STRUCTURE

The spiral configurations associated with sun-spots, described in my paper "Solar Vortices,"[2] were there called "vortices" for two principal reasons: their forms closely resemble vortices, and the phenomenon photographed by Dr. St. John on June 3, 1908, appeared to represent a mass of hydrogen in the act of being sucked into a spot. On the hypothesis that such vortices in the solar atmosphere might give rise to magnetic fields in sun-spots, the Zeeman effect was sought and immediately found. Right- and left-handed vortices were then shown to be of opposite polarity. As the only known means of producing a solar magnetic field, similar to that observed in spots, is the rapid revolution of electrically charged particles, we may safely conclude that sun-spots are vortices.

For reasons already mentioned, I came to the conclusion that the vortex which produces the field must lie within the photosphere. The hydrogen lines in spot spectra show no indication of the Zeeman effect and hence the field is very weak at high levels. It does not follow, however, that the revolution of electrically charged particles at the level represented by *Hα* produces no magnetic field. The field may be too weak to give an appreciable Zeeman effect, or it may be opposite in sign to the field originating at a lower level, which would thus partially or wholly counteract it. The relative proportion of positive and negative electrons probably differs at different levels in the solar atmosphere. A preponderance of positive electrons at one level, and of negative electrons at another, if whirled in the same vortex would produce fields of opposite sign.

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[1] A spectroheliograph of this kind might give interesting results if used with a Nicol and quarter-wave plate or Fresnel rhomb. If one camera slit were set on the red component of a Zeeman quadruplet, and the other on the violet component, two photographs secured simultaneously should record separately regions having magnetic fields of opposite polarity. On account of the strong general absorption, the method is not likely to apply well to spots, but it may be useful in detecting weak fields in other parts of the Sun. For this purpose high dispersion is required, and the camera slits must be set only a short distance to the red and violet of the center of the line. A line which is narrow in the solar spectrum, and widely separated by a magnetic field, should be chosen for the work. Differences in the separation of the components, due to fields of different strength, should not be an insuperable obstacle. In some cases it may be advantageous to photograph regions in which a line is merely widened, without complete separation. For this purpose an ordinary spectroheliograph, with single camera slit, may be employed, with or without a Nicol and quarter-wave plate.

[2] *Contributions from the Mount Wilson Solar Observatory,* No. 26; *Astrophysical Journal,* **28,** September, 1908.

EVERSHED'S recent spectroheliographic results indicate that there is an outward flow, parallel to the photosphere, from the center of sun-spots at the iron level, and an inward flow at the H_3 level. Although the flow was at first considered to be radial, a tangential component has since been detected, so that the observed phenomena, at the H_3 level, are brought into harmony with those shown in spectroheliograph images of the *Hα* flocculi.

In my paper on "Solar Vortices" I called attention to the exact correspondence between the analytical relations developed in the theory of vortices and the theory of electro-magnetism. This identity shows why hydrodynamical phenomena sometimes cannot be distinguished in appearance from the corresponding electro-magnetic phenomena. BJERKNES has given many interesting illustrations of such agreement in his work "Die Kraftfelder."

In spite of the phenomenon of June 3, 1908, and the support afforded by EVERSHED'S recent investigations, the hydrodynamical theory cannot be said to be superior in all points to the electro-magnetic theory of the hydrogen flocculi. Moving electrons would undoubtedly be deflected by the magnetic fields in sun-spots, and the apparent lines of force which frequently unite spots of opposite polarity seem highly suggestive. However, it should be possible to find criteria which will enable us to decide whether these lines are produced by the magnetic fields themselves, or are of hydrodynamical origin.

We may first recall that the apparent vortex structure is best shown on spectroheliograms made with the camera slit set at some point between the center and edge of the *Hα* line.

Such structure is less clearly shown with the more refrangible hydrogen lines, which represent a lower level in the solar atmosphere.[1] However, $H\delta$ often shows the apparent lines of force between two spots, though it fails to bring out some of the most remarkable structure photographed with $H\alpha$. Even the H_2 flocculi have a similar structure, which is easily recognized when we know that spots of different polarities often occur in the same group. We may even detect evidences of the operation of the same force in the structure of the H_1 flocculi and the faculæ. The striking resemblance between the $H\alpha$ flocculi and the penumbral filaments of LANGLEY's exquisite drawings, to which I have alluded in previous papers, apparently completes the connection between the upper and lower levels. Opposite directions of curvature of the penumbral filaments in different parts of the spot group should in this case mean opposite polarities. This is being tested, and a comparative study of penumbral and $H\alpha$ structure is also in progress.

In a recent paper DESLANDRES suggests that the failure of the H_2 photographs to show the apparent lines of force is due to the greater mass of the calcium ion, which would be less deflected by the field than the hydrogen ion.[2] We have seen, however, that apparent lines of force having about the same curvature as the dark $H\alpha$ flocculi are frequently shown by H_2 between spots of opposite polarity, though this line fails to give most of the finer details of the $H\alpha$ structure. The difference may be due in large part to the greater effect of convection current at the H_2 level. The apparent lines of force, or vortex structures, are best shown in the higher atmosphere, where the slowly descending gases are less affected by other influences. The very strong field at low levels should deflect moving ions much more than the very weak field at the $H\alpha$ level, but possibly convection may conceal such an effect.

Another mode of attacking the question avoids the convection difficulty. On the aurora hypothesis it is only reasonable to suppose that large spots, having strong magnetic fields, should be capable of defining the structure of the hydrogen flocculi at a much greater distance than small spots, having weak fields. Nevertheless, we find in practice that some groups of very small spots, like that of April 30, 1908, are surrounded by a great cyclonic structure in the hydrogen flocculi, extending over a distance equal to about one third of the Sun's diameter, while it is frequently true that large spots, with strong magnetic fields, seem to influence the form of the flocculi over a very much smaller area. Thus it can hardly be said that such evidence is favorable to the electro-magnetic explanation, particularly when it is remembered that beautiful cases of apparent lines of force or vortex structure, covering great areas, are frequently shown on *Hα* photographs in regions where no spot is present.

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[1] *Proceedings of the Royal Society*, A. **83**, 177, 1909.

[2] *Loc cit.*

The questions raised in these notes will be discussed more fully in a paper containing the quantitative results of the present investigation, which will soon be published. A single suggestion may, however, be added here. If the apparent lines of force uniting two spots of opposite polarity are of hydrodynamical origin, they suggest that one spot should be regarded as a source and the other as a sink. As EVERSHED's published results all indicate an inward flow at the H_3 level, the existing data seem to be opposed in this case to the hydrodynamical explanation.

A REVIEW OF THE RECENT OBSERVATIONS OF *MARS*.[1]

By R. G. AITKEN.

It is my purpose this evening to give you a short account of the recent observations of *Mars*, and of the general conclusions that I think may fairly be drawn from these observations. As a man's opinions are necessarily influenced in a greater or less degree by his experience and training, it may be well to premise that I speak from the point of view, not of the expert areographer, but of the interested student, who has familiarized himself with the literature of the subject and who has also had many opportunities during the past sixteen years to study the planet directly, under favorable observing condi-

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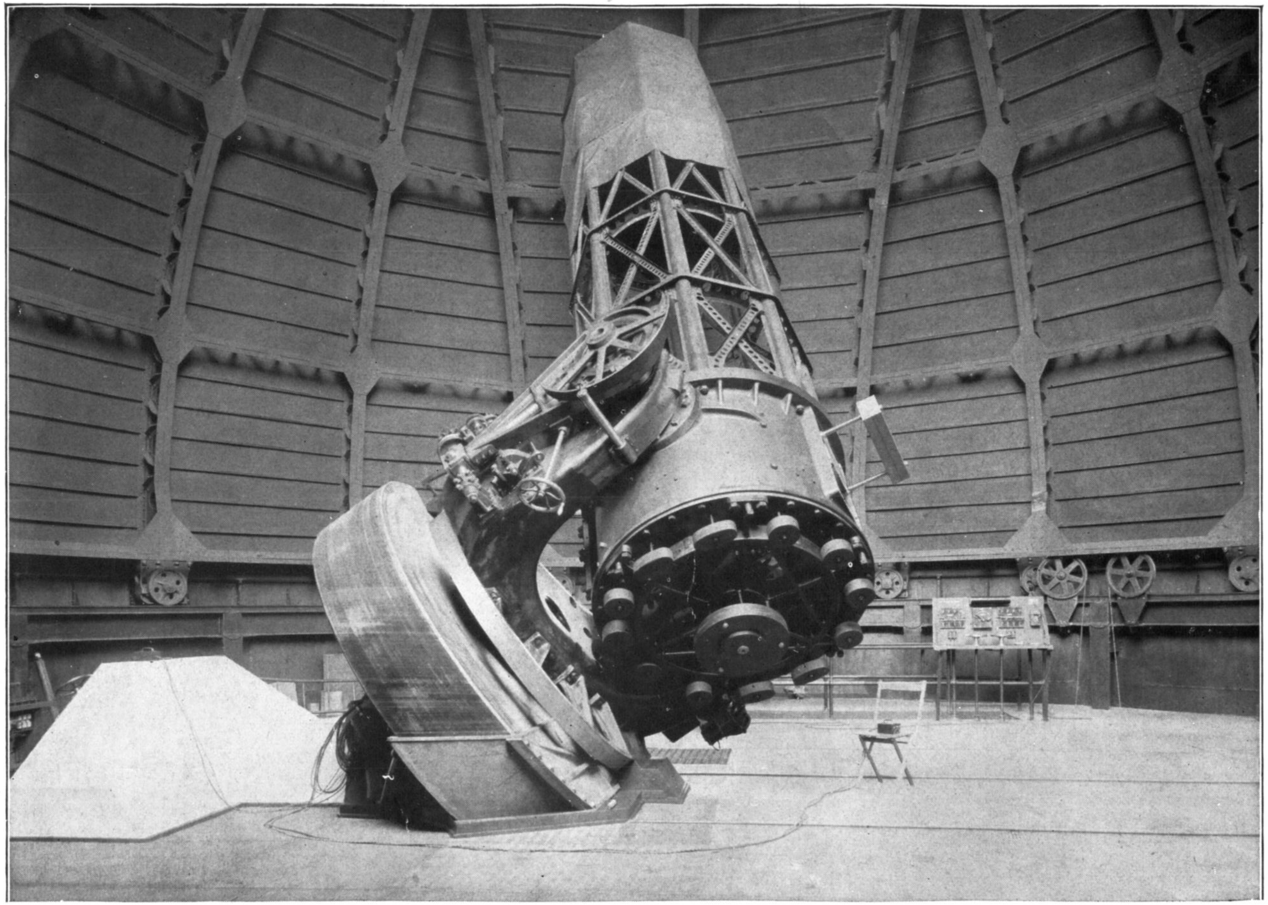
[1] This is an abstract of an address given before the Society at its annual meeting on March 26, 1910. Lantern slides of drawings and photographs of *Mars* made during the last three opposition periods were exhibited to illustrate the address.



SIXTY-INCH REFLECTOR, MOUNT WILSON SOLAR OBSERVATORY.